Annual Report

Selective response of precipitation to temporally and spatially varying forcing of soil moisture (GC03-322)

Project period: May 2003 – April 2006
Report period: May 2004 – April 2005
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1. Project description

This project aims at understanding the impact of the variability in land surface forcing on the variations of North American precipitation, in particular, the *selective* response of precipitation to temporally and spatially varying soil moisture forcing. Work is conducted using the Eta Regional Climate Model, NCEP LDAS Data, NCEP Regional Reanalysis, U.S. Unified Daily/Hourly Precipitation Data, NCEP/NCAR Global Reanalysis, and others. Specifically, the project addresses the following questions:

(a) If soil moisture can be specified to represent different timescales, how will precipitation vary correspondingly?
(b) Will the monthly-seasonal means of precipitation be affected by the change on timescales (e.g., from diurnal cycle to others) of soil moisture forcing?
(c) If soil moisture can be specified to represent different spatial scales, how will precipitation vary correspondingly?
(d) How will the soil moisture in a specific region affect the variability of precipitation in a larger region?
(e) How will the changes in temporal and spatial scales of soil moisture affect the roles of forcing initialization and memory in precipitation variability?
(f) How are the above features different between dry and wet regions, and between dry and wet seasons?

2. Work accomplished during the report period (May 2004 – April 2005)

(a) Testing and experiments with the Eta Regional Climate Model

During first few months of the report period, we have experimented with the Eta Regional Climate Model to assess the importance of initial conditions and initial land states data for the simulations of 1988 and 1993 U.S. summer climate.

We first conducted experiments with the model using initial land states data from the NCEP/NCAR Global Reanalysis: Eta(GRII). For both 1988 and 1993, the starting month of model simulations was May. This enabled us to carry out a comparison of the output with that from previous experiments in which the starting month was December (i.e. December 1987 and December 1992, respectively). Results from the comparison indicate that the initial conditions (or the lengths of model integration) affect the results of simulation for the target summer climate. Figure 1 shows the precipitation patterns of July 1993 simulated by experiments with different starting months. It can be seen that the heavy precipitation associated with the Midwest flood was captured better in (b) with the starting month of May 1993 than in (a) with the starting month of December 1992.

We then conducted more experiments with the model using initial land states data from the NCEP Regional Reanalysis: Eta(R/R). We carried out 5-member ensemble experiments for both 1988 and 1993, starting from the month of April. We compared the results from Eta(R/R) with those from Eta(GRII), and with observations and reanalysis data (see section 2b).

(b) Diagnostics of model results and comparison of model with observations & reanalysis data

With an emphasis on Eta(R/R), we have analyzed the results from different experiments and compared them with observations and reanalysis products. For both 1988 and 1993, we also compared the features of each ensemble member versus ensemble means, and found strong correlation among them in area-averaged sea surface pressure. Figure 2 shows the June patterns of difference in precipitation between 1993 and 1988 in (a) ensemble means of Eta(R/R), (b) ensemble means of Eta(GRII), (c) NCEP Regional Reanalysis, and (d) CPC Unified Analysis. While there is an apparent resemblance between the model output (using different initial land states; (a) and (b)) and between the "observations" ((c) and (d)), the Eta model does show capability in simulating the difference between the 1993 flood and 1988 drought in the Midwest and Great Plains regions. Overall, Eta(R/R) seems to perform better than Eta(GRII), but their relative performance changes with time.

Figure 3 presents patterns similar to those in Fig. 2, but for surface temperature. Here, the "observed" temperature is from the NCEP Regional Reanalysis (c) and the Global Telecommunications System (d). Again, the model captured the difference between 1993 and 1988 reasonably well. It seems that the unrealistic feature in the upper-right corner of the figure is less apparent in Eta(R/R) than in Eta(GRII).

Figure 4 shows the patterns for another important field, soil moisture, for May (left panels) and June (right panels). There is a clear similarity between the model results (top and middle panels) and NLDAS data (lower panels). Relatively, Eta(R/R) ((a) and (d)) produced more realistic soil moisture patterns than does Eta(GRII) ((b) and (e)).

(c) Further model experiments

We have finished the construction of surface boundary forcing data for further experiments in which the model is forced by different soil moisture conditions. In other words, the soil moisture information on different temporal and spatial scales, from both regional reanalysis and model output and for both 1988 and 1993, is ready to use in the experiments. For example, Figs. 5 and 6 show the difference in model produced soil moisture between different time scales (daily versus monthly; Fig. 5) and between different spatial scales (0.25° (lon. x lat.) versus others; Fig. 6). It is believed that these differences in soil moisture on temporal and spatial scales will cause different response in the atmosphere. For the reanalysis data, we have examined both the NLDAS and NCEP Regional Reanalysis products. Because problems may exist in the vegetation maps used in NLDAS (Drs. Yun Fan and Rongqian Yang, personal communications), we decided to use the soil moisture information from the NCEP Regional Reanalysis as the surface boundary forcing of the model, using initial land states data from the NCEP Regional Reanalysis as well (see section 2a). Currently, we are working on the codes of the model and expect to finish the experiments within a few months.

3. Publications

Li, Q., S. Yang, V. E. Kousky, R. W. Higgins, K.-M. Lau, and P. Xie, 2004: Features of cross-Pacific climate shown in the variability of China and United States precipitation. *Int. J. Climatol.,* to be submitted.

Yang, S., X. Ding, and D. Zheng, 2004: Variations of the U.S. Great Plains precipitation and its relationship with tropical central-eastern Pacific SST. *J. Climate.,* submitted.

4. Meetings

Partial support to the 4th International Symposium on Asian Monsoon System, 24-29 May 2004, Kunming, China (Presentation: Extratropical atmospheric and land surface effects on the Asian summer monsoon)

The 1st International CLIVAR Science Conference, 21-25 June 2004, Baltimore, MD

GAPP PIs Meeting, 30-31 August 2004, Boulder, CO (Presentation: Simulations of the U.S. precipitation in 1988 and 1993 by the NCEP Eta Regional Climate Model)

5. Plan for the next year (May 2005 – April 2006)

(a) Model experiments

We will continue and finish the experiments in which the Eta model is forced by different soil moisture conditions (see section 2c). Again, they will be 5-member ensemble experiments in which soil moisture information on different temporal and spatial scales is applied to force the model, for both 1988 and 1993. The NCEP Regional Reanalysis product is used for both initial land states and surface boundary conditions.

(b) Analysis of model output

The major effort during this period will be devoted to the analysis of model output, in comparison with observations. We will address the scientific issues as raised in section 1. There will be a large amount of data to analyze, including the 3-hourly data from the various model experiments and the regional reanalysis products. However, because we have the specific target issues in mind, we expect a smooth and successful analysis and will provide useful information for addressing the various target problems.

(c) Result publications

Write papers and publish the results in professional journals.

6. Contacts

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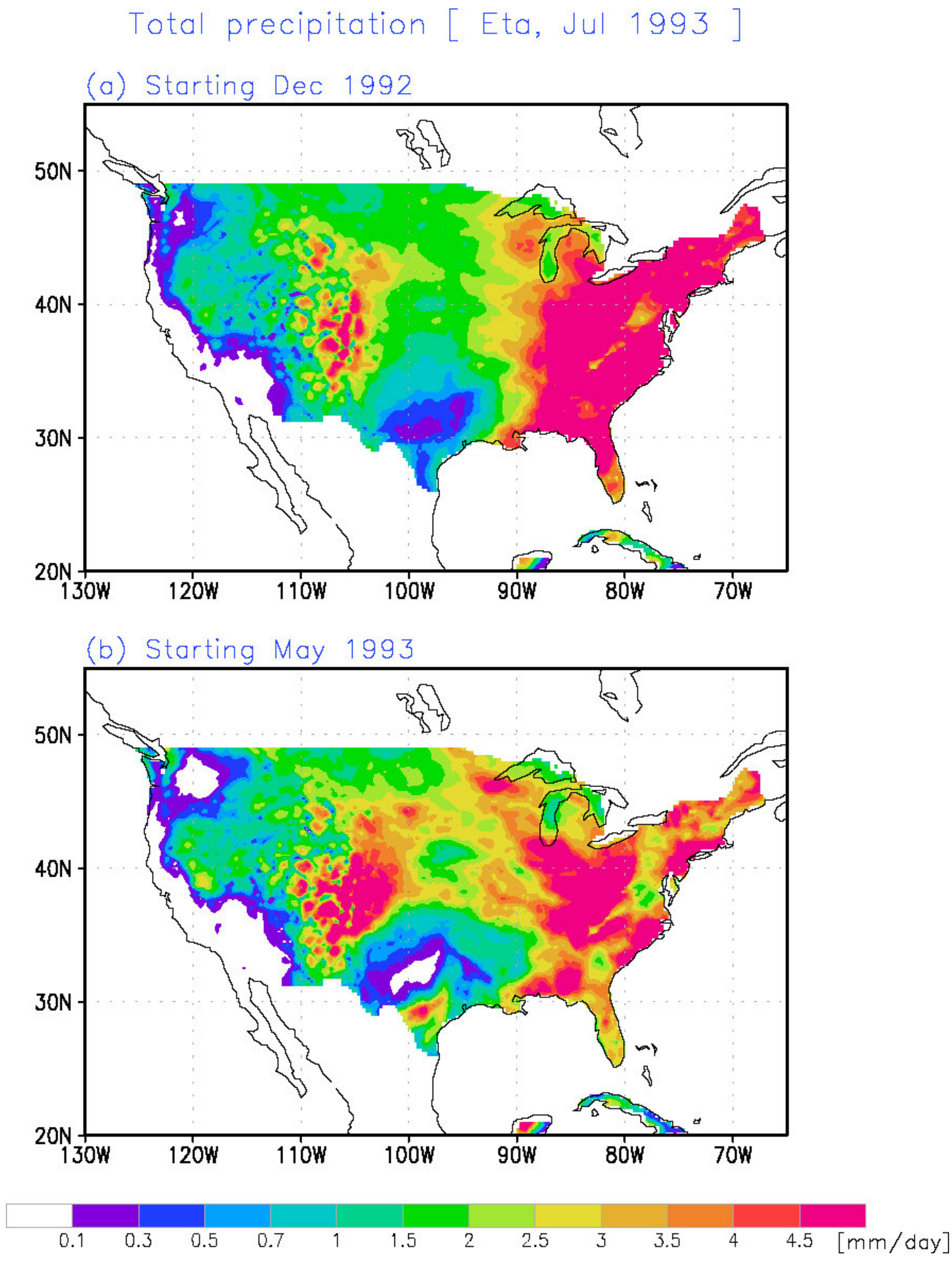

Fig. 1. Precipitation patterns of June 1993 simulated by Eta(GRII) starting in December 1992 (a) and May 1993 (b).

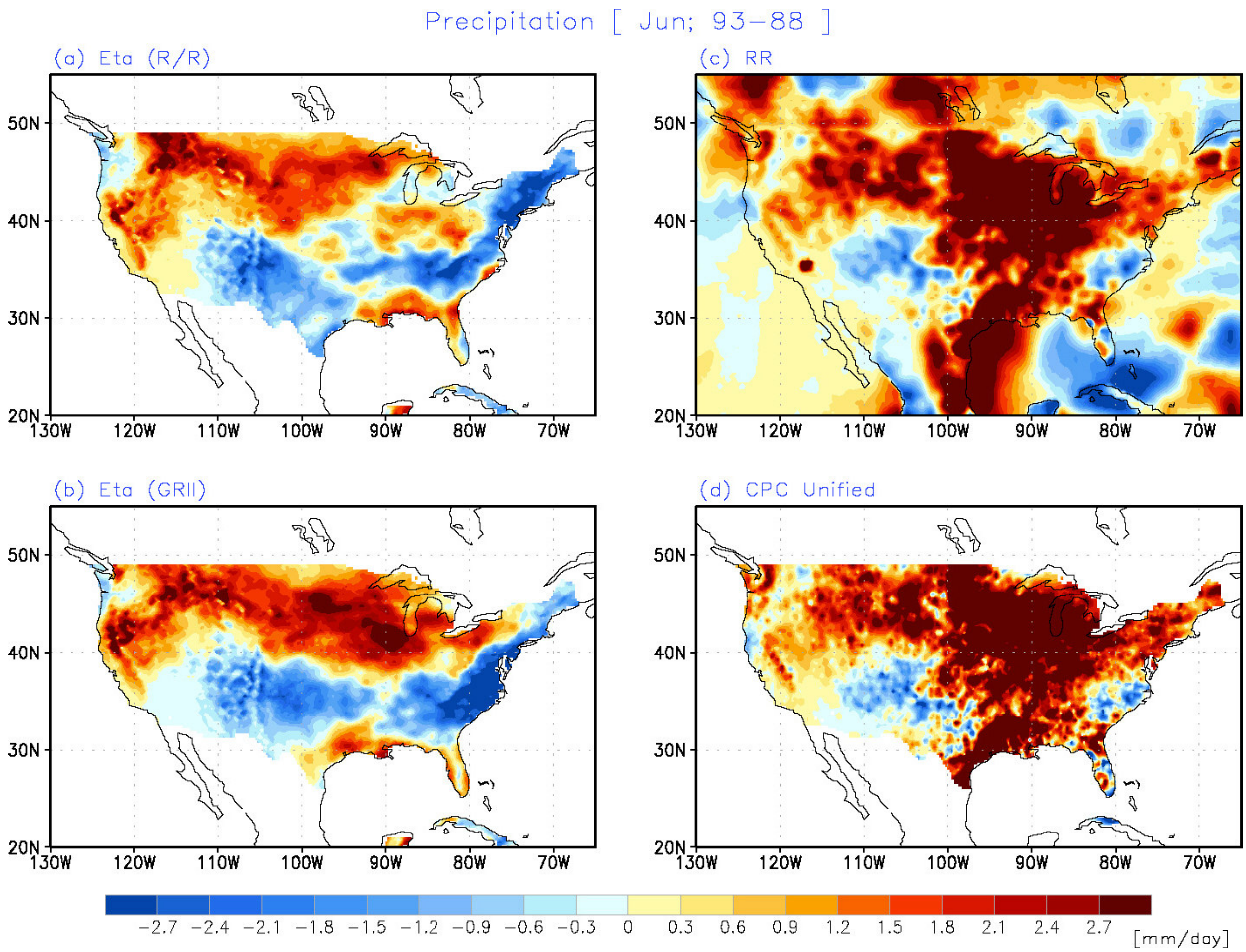

Fig. 2. Difference in June precipitation between 1993 and 1988. Note the similarity and difference between experiments Eta(R/R) and Eta(GRII) on the left hand side, and those between the model experiments and "observations" (NCEP Regional Reanalysis in (c) and CPC Unified Analysis in (d)).

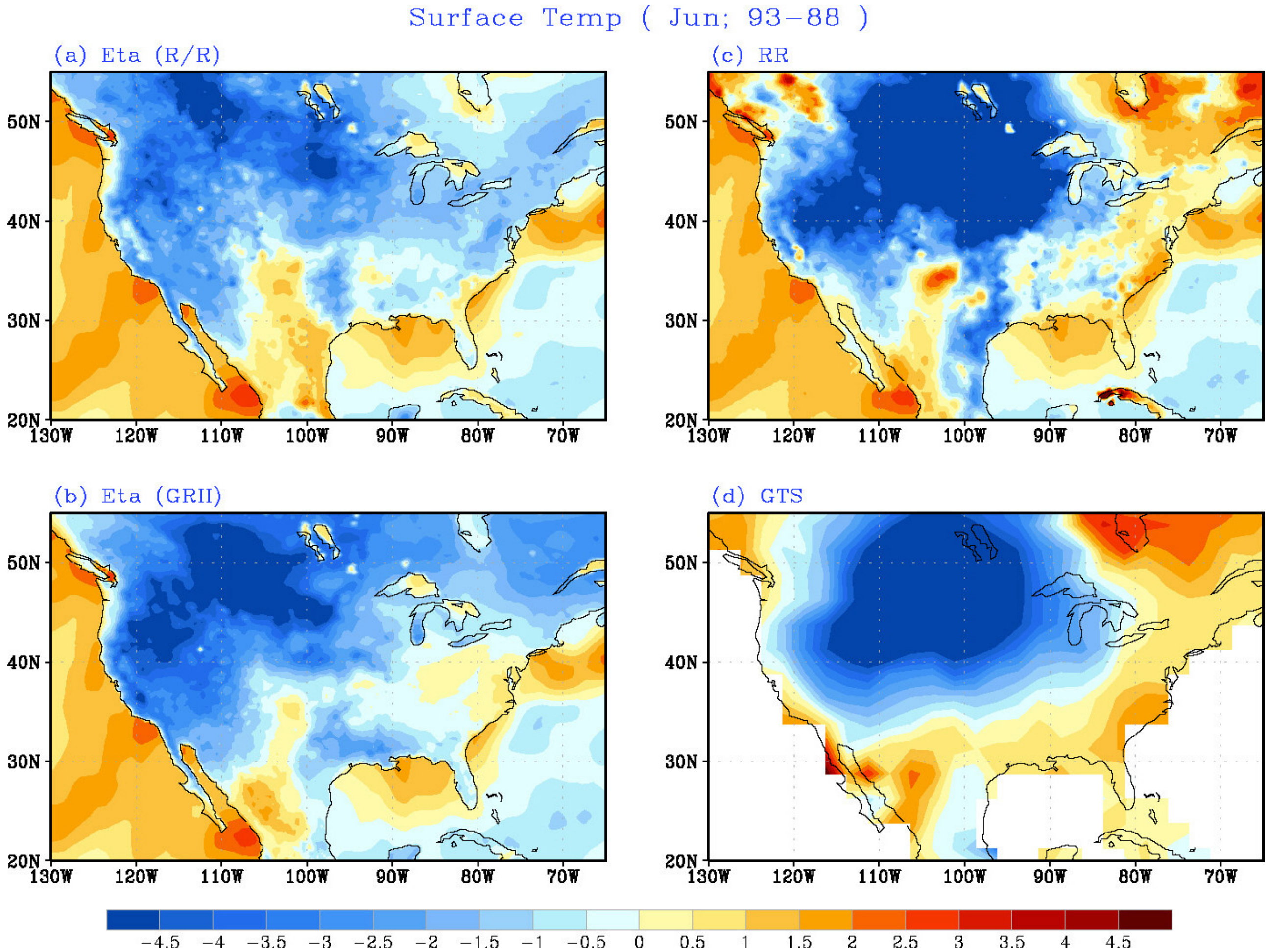

Fig. 3. Difference in June surface temperature between 1993 and 1988. Note the similarity and difference between experiments Eta(R/R) and Eta(GRII) on the left hand side, and those between the model experiments and "observations" (NCEP Regional Reanalysis in (c) and Global Telecommunications System in (d)).

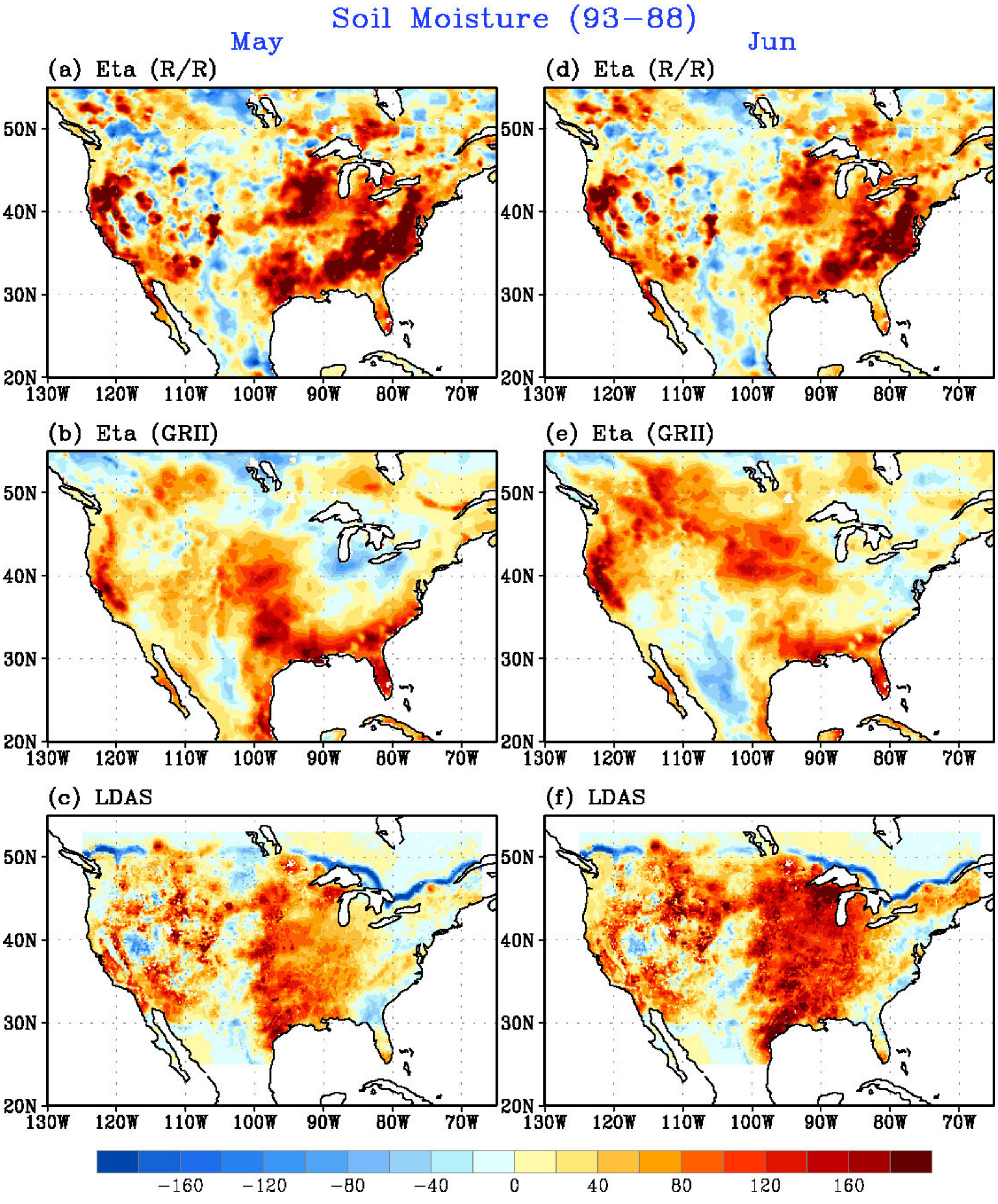

Fig. 4. Differences in soil moisture of May (left) and June (right) between 1993 and 1988. Note the similarity and difference between experiments Eta(R/R) and Eta(GRII) in the top and middle panels, and those between the model experiments and the NCEP Land Data Assimilation System in the bottom panels.

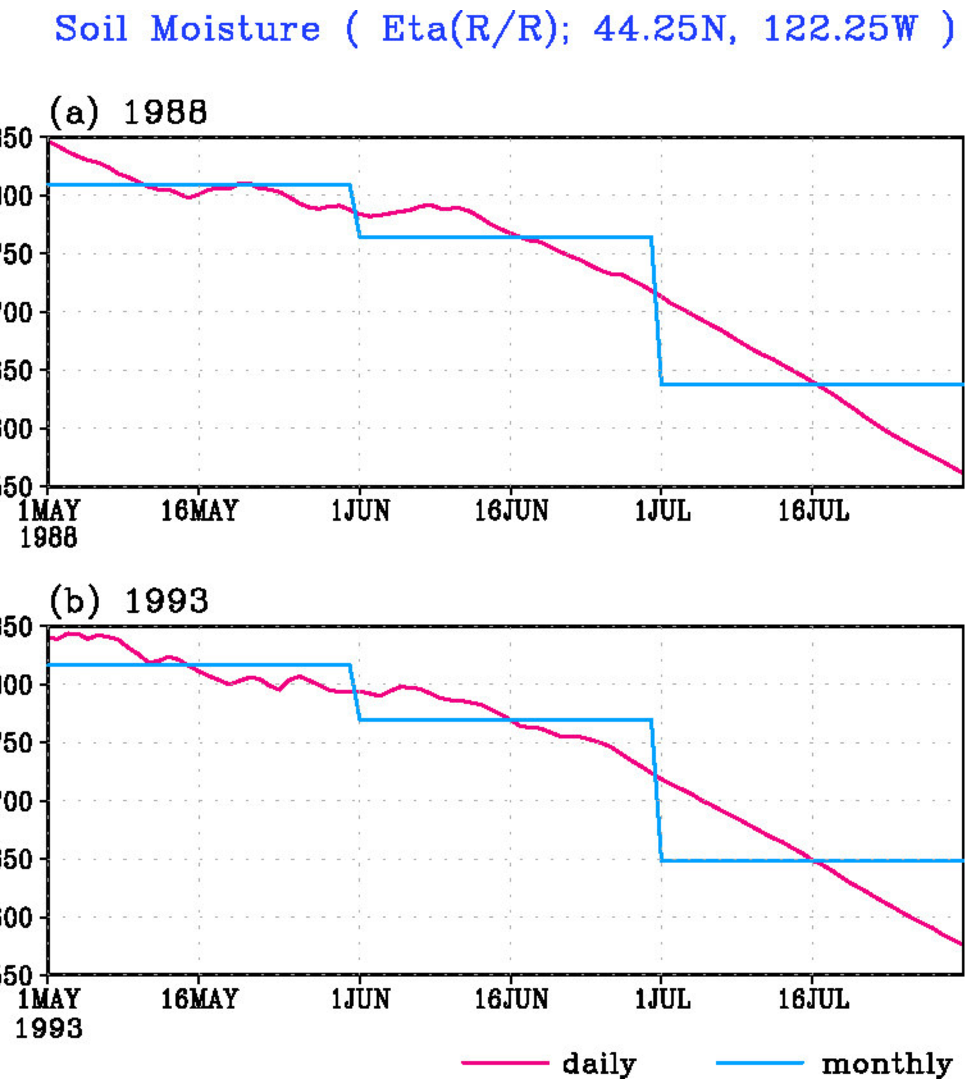

Fig. 5. Daily (red lines) and monthly (blue lines) soil moisture at 44.25°N/122.25°W for 1988 (upper panels) and 1993 (lower panels). The figure, for Eta(R/R), serves as an example of forcing functions for investigating the response of the atmosphere (precipitation, temperature, circulation, and others) to the temporal variability of soil moisture in sensitivity experiments.

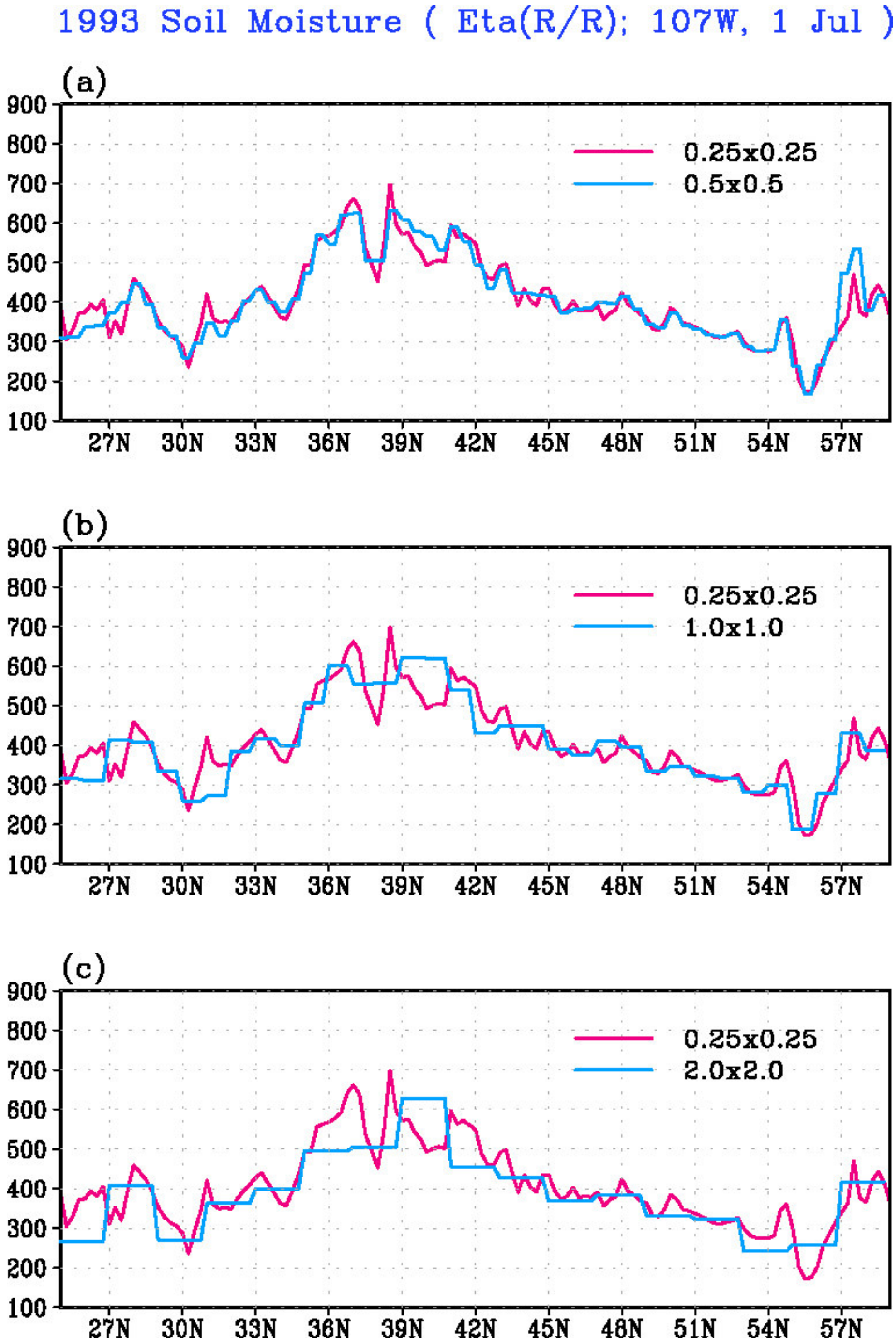

Fig. 6. Soil moisture of 1 July 1993, along the longitude of 107°W, in Eta (R/R). Shown are the values of original grid points (red lines) and those averaged over various areas (blue lines). The figure serves as an example of forcing functions for investigating the response of the atmosphere (precipitation, temperature, circulation, and others) to the spatial variability of soil moisture in sensitivity experiments.